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## Introduction

Modern interest in the study of language and the brain emerged out of the confluence of several independent research initiatives. In linguistics, research has been dominated since the 1960s by the theory of generative grammar, originally developed by Noam Chomsky. A central tenet of Chomsky's theory is that linguistics is, in fact, a branch of theoretical biology; under this view, a theory of grammar is a theory of how the brain organizes and represents knowledge of language (e.g., Chomsky, 1965). Simultaneous with the emergence of generative grammar and quite independent of that, the American neurologist Norman Geschwind had become interested in the writings of the late 19th and early 20th century European neurologists who had studied language and the brain. Geschwind reintroduced this work and, synthesizing it, laid out a model of language organization in the brain (Geschwind, 1965). In 1967, in *Biological Foundations of Language*, Eric Lenneberg attempted to bring together what was known from neurology (including neuroanatomy) and linguistics (including psycholinguistics) to provide the basis for explorations in the biology of language. Despite the significance of the work of each of these men, through the early 1970's little systematic attention was given to neurolinguistics and only rarely were there attempts to build on this initial background (e.g., Whitaker, 1971). Suddenly, in the mid-1970s there was a burst of active research, and since then there has been a rapid proliferation of interest in studying various aspects of language and the brain.

Research on aphasia has held a central place in the development of neurolinguistics over the past two decades. From linguistics, we have the assumption that all human beings are biologically endowed with a specific capacity to acquire, know, and use a language given normal experience in a speech community; that is, there must be some biologically dedicated neural system(s) for linguistic capacity. This assumption, coupled with the consistent observation from neurology that the breakdown of language is not random, but rather has a systematic pattern, makes the study of aphasia an obvious context for investigating human linguistic capacity, in general, and language and the brain, in particular. From the onset of linguistically and

psycholinguistically based aphasia research in the mid-1970s, Broca's aphasia has been the dominant area of inquiry. This has occurred, I believe, for three pragmatic reasons: First, Broca's aphasics have, in normal discourse, relatively spared comprehension and thus, in contrast to some other populations, are fairly reliable as subjects — one need not worry inordinately whether a patient's performance on a task reflects a failure to understand the task demands themselves. Second, Broca's aphasics typically present a striking and intriguing deficit in language production, agrammatism — the systematic tendency to omit function words and omit or misuse various inflections. Finally, Broca's aphasia is a relatively common form of aphasia, so there are subjects available for research.

In this paper I will focus on studies of sentence comprehension in Broca's aphasia. In the first section, my emphasis will be on work which was carried out between the mid-1970s and mid-1980'. This work did much to establish the questions which have been of primary research interest since and, as importantly, to determine what areas would be ignored. In the second section of the paper, my emphasis will be on work done largely in the last decade. This work is striking for a number of reasons. First, unlike the majority of experimental research carried out with neurologically intact populations, a great deal of this research has been explicitly guided by linguistic theory. Second, a significant proportion of this work has been carried out with the goal of relating data on pathological processing of language to theories of the representation of linguistic capacity.

### 1. *What is the Domain of Study?*

In my view, two distinct avenues of investigation can be said to provide the starting point for the modern spate of activity in neurolinguistic studies of Broca's aphasia, the first being the development of awareness of a comprehension deficit and the second being the attempt to develop formal analyses of the disorder. Wernicke (1874) had observed that there were some comprehension problems associated with Broca's aphasia, but these were not considered a core or significant component of the disorder; the central deficit of Broca's aphasia was seen as lying in the domain of language production. This view was consistently maintained in neurology, psychology, and neuropsychology texts for more than a century, and, indeed, it is still found in many standard texts (e.g., Gleitman, 1995). However, in the 1970's, papers began appearing which reported a systematic comprehension deficit in Broca's aphasia (Parisi and Pizzamiglio, 1970; Lesser, 1974; Caramazza and Zurif, 1976; Heilman and Scholes, 1976; Zurif and Caramazza, 1976). The most influential of these reports (in terms of citations) were Caramazza and Zurif's (1976) and Zurif and Caramazza's (1976) papers in which it was reported that subjects with Broca's aphasia performed poorly on sentence comprehension and metalinguistic tasks with a variety of sentence types, notably reversible passive sentences. Because correct interpretation of passive sentences involves tacit cognizance of the grammatical role of function words and

inflection, findings such as these were taken as evidence that Broca's aphasia involves a parallel deficit in production and comprehension. Caramazza and Zurif hypothesized that the disruption underlying agrammatism of speech and comprehension involved an inability «to compute full syntactic representations.» This view was supported by subsequent studies of sentence understanding. While work such as that of Caramazza and Zurif was informed by psycholinguistic and linguistic concerns, that work made little attempt to provide any *formal* characterization of the impairment of Broca's aphasia; their proposal, for instance, was that patients encode semantic relations based largely on lexical content and plausibility rather than computing syntactic structure.

Kean (1977) presented the first detailed attempt at providing a formal analysis of the deficit(s) associated with Broca's aphasia. In that analysis, based on the assumption of parallel deficits in production and comprehension, the goal was to see if it was possible to account for the general range of deficit data typically ascribed to agrammatic Broca's aphasics under a single representational hypothesis. The previous research on agrammatism had provided evidence of compromises in both the syntactic and semantic analysis of sentences in the manifest performance of patients. The loci of overt deficits are not, however, necessarily the locus/loci of the underlying deficit(s) which give rise to observed behavioral limitations. The full computation of a linguistic representation involves a partially ordered set of stages. An impairment at any single stage can, in principle, lead to overt limitations in the products of other stages because well-formed inputs to the impaired level(s) of representation/processing will be distorted by the impairment(s) and the ill-formed outputs of the impaired level(s) will inevitably lead to a lack of well-formedness in the outputs of succeeding unimpaired levels. In Kean (1977) it was argued that the then known features of agrammatism could be accounted for in terms of phonological representations rather than syntactic and/or semantic representations. Specifically, it was proposed that agrammatism of speech and comprehension involve a tendency to reduce a string to the minimal sequence of well-formed phonological words. As items such as articles, non-lexical prepositions, and auxiliary verbs are not, from a grammatical perspective, independent words but rather affixes, this hypothesis predicts a tendency toward their omission. With regard to inflections, the hypothesis makes different predictions for relatively uninflected languages like English than it does for more richly inflected languages like Spanish. In the case of English, a noun stem and its minimal well-formed word are typically one and the same, e.g., *dog, house, woman*; this is also the case with verbs, e.g., *walk, eat, sleep*. In Spanish, by way of contrast, noun stems are not typically well-formed words, e.g., *perr-, cas-*, but *mujer*; verb stems, likewise, are not minimal well-formed words, e.g., *and-, com-, dorm-*. It was argued that in a language such as Spanish, the minimal phonological word was typically the standard unmarked (citation) form of the item; thus, it was predicted that in agrammatism there would be a tendency toward the production of singular nouns and infinitives, e.g., *perro, casa, mujer, andar, comer, dormir*. In languages which mark case on nouns, this hypothesis predicts a tendency toward the use of the nominative singular. It was argued that if agrammatism involves the tendency to reduce

strings to sequences of minimal phonological words then it would follow that agrammatic aphasics would be unable to fully compute syntactic representations, as Zurif and Caramazza (1976) had hypothesized. While Kean (1977) was this first attempt at a formal analysis, it held a key property in common with its predecessors: Specifically, this is a descriptive analysis of the impairment and does not provide an account of the underlying source of agrammatism.

In 1983, the thesis that agrammatism might involve a parallel deficit in all facets of language use was, apparently, dealt a fatal blow by Linebarger, Schwartz, and Saffran. In their research, three agrammatic aphasic patients were asked to make grammaticality judgments. The data analysis suggested that these patients had a relatively preserved ability to make grammaticality judgments. If this were so, then it would have to follow that these patients were capable of computing syntactic structures. This is, in fact, the conclusion Linebarger, Schwartz, and Saffran draw. To account for agrammatism, they propose the «mapping hypothesis». Under this hypothesis, the deficit of Broca's aphasics involves a compromise in the mapping from well-formed and complete syntactic representations onto semantic representations—in particular, a compromise in the ability to map grammatical functions to semantic roles. Their notion of what the syntax-to-semantics mapping function is and the nature of the resulting semantic representation is, however, left undefined.

There is, however, a devastating conceptual problem with the grammaticality judgment research of Linebarger and her collaborators. It is based on the assumption that when an aphasic patient says that a grammatical sentence is indeed grammatical that they are computing the same syntactic representation of the sentence as would a normal neurologically intact individual. However, there is no basis for making such a radical assumption. Consider, for example, the sentence in (1):

*1. Sally promised Mary to wash the dishes, and she did.*

Two individuals could agree that this was a grammatical sentence, but from that it would not necessarily follow that they were computing the same syntactic and formal semantic representations; one of the subjects could interpret the sentence as meaning that Sally washed the dishes while the other could incorrectly interpret the sentence as meaning that Mary washed the dishes. It is only in the former case that the subject can be argued to have provided the 'correct' grammaticality judgment; in the latter case, while the judgment is apparently correct, probing demonstrates that the judgment is, in fact, not correct in the sense that the appropriate structure had been computed. Thus, to assess an individual's grammaticality judgment, one needs not only a yes/no response but also some independent data on the basis of that judgment in order to interpret the yes/no response. This is the critical issue which Linebarger and her colleagues failed to take into account.

My colleague Charlotte Koster and I carried out a judgment study in which we not only asked subjects to make judgments but also probed those judgements in order to determine their

basis, thereby overcoming the crucial problem with the Linebarger, Schwartz, and Saffran (1983) study. Our subjects included 36 healthy adults and 18 Broca's aphasics; all the subjects were native speakers of Dutch. The test consisted of 54 sentences; for each sentence, the subject had to make a judgment and then that judgment was probed. Example sentences and the probes are given in (2).

2. a. *Hans beloofde Thomas niet over zichzelf te praten*

Hans promised Thomas not to talk about himself

Probe: I'll let you hear it again. Pay attention ... Who will not be talked about?

b. *Hetty overtuigde Inge een nieuwe jurk voor zichzelf te kopen*

«Hetty convinced Inge to buy a new dress for herself»

Probe: I'll let you hear it again. Pay attention ... Who bought a dress?

While all 36 of the control subjects provided 'correct' judgments, i.e., said that the sentences were grammatical, and 'correct' probe responses for such sentences, only 4 of the Broca's aphasics consistently provided correct judgments and correct probe responses for sentences like those in (2); the remaining 14 Broca's subjects typically judged the sentences to be grammatical but were individually inconsistent in their probe responses, sometimes identifying the correct actor and sometimes identifying the incorrect actor. Among our other findings was that all the Broca's patients were inconsistent in their judgments of the grammaticality of ungrammatical sentences both within and across types of sentence structures and of the grammaticality of certain classes of well-formed sentences (e.g., those involving nesting). Other researchers have also noted that Broca's aphasics are compromised in their abilities to make correct grammaticality judgments to some noticeable degree on some sentence types (e.g., Hagiwara, 1995; Grodzinsky, 1996). Thus, the claim that Broca's aphasics have relatively intact judgment capacities, as Linebarger, Schwartz, and Saffran (1983) argued, is not supported either conceptually or empirically. That notwithstanding, the impact of the original judgment work has been to significantly undermine the hypothesis of parallelism.

The thesis of parallelism was also dealt a blow by work which purported to show that agrammatism of speech could occur in patients with intact comprehension (Goodglass and Menn, 1985; Kegl, 1996; Kolk, van Grunsven, and Keyser 1982; Miceli, Mazzuchini, Mann and Goodglass, 1983; Friedmann and Grodzinsky, 1994, Nespoulous et al., 1984). Where there are anatomical data reported, the patients do not have a left frontal lesion as is neuroanatomically definitional of Broca's aphasia. For example, the patients reported by Kolk et al. (1982) and Kegl (1995) have parietal lobe lesions, while the CT of the patient described by Friedmann and Grodzinsky (1994) is described as «showing no signs of stroke» but «reveal[ing] an asymmetry in the size of the lateral ventricles, the left being substantially enlarged. It also shows an enlarged sylvian fissure. "Largely unnoted in the discussions of the data of Linebarger and her colleagues is the fact that the three patients they studied do not have 'classic' Broca lesions consequent to stroke. It is also significant that a number of the patients in this group of good comprehending 'agrammatics'

do not seemingly show typical agrammatic production profiles. For example, the patient discussed by Friedmann and Grodzinsky (1994), who has been extensively studied, has a highly selective deficit; her impairment is restricted to production involving (a) tense but not agreement, (b) copular constructions, and (c) realization of sentential subjects; the patient reported by Nespoulous et al. (1984) also seemingly has the same highly restricted deficit. One of the patients studied by Miceli et al. (1983) was not agrammatic in reading and was able to repeat. Thus, it is clear that some variant(s) of agrammatism of speech, but *not* comprehension or judgment, can be found in patients without Broca's lesions. What has not been shown, however, is a patient with a classical Broca's lesion (modulo considerations of depth of lesion and disconnection) who demonstrates agrammatism of speech in the absence of an impairment in comprehension and production. The data available would seem to argue that locus of lesion is a critical variable which must be taken into account if generalizations about the representation of language and the brain are to be drawn from behavioral data from aphasic patients. One cannot assume that some essentially intuitively defined phenomenon such as agrammatism is a uniform deficit across patient populations independent of locus of lesion; rather both lesion site and a constellation of symptoms seem to be critical for developing coherent and general analyses. This observation should in no way be considered surprising since it is well-attested in other areas of neuropsychology (e.g., the differences between patients with amnesia consequent to hippocampal (limbic) lesions vs. those with diencephalic lesions). If anything is surprising, it is that in the domain of aphasia research this has not been acknowledged in practice to any notable degree.

Both the grammaticality judgment research, which includes numerous papers in addition to the original work of Linebarger et al. (1983) (e.g., Wulfeck, Bates and Capasso, 1991; Shankweiler, Crain, Gorrell, and Tuller, 1989) and the reports of so-called anomalous cases of agrammatism without a comprehension deficit have had the seeming consequence of freeing investigators to focus on particular facets of disorders. In the domain of agrammatism and Broca's aphasia, the facet which has received the greatest attention is comprehension.

## *2. Two Approaches to Agrammatism in Comprehension*

Given the scope of the literature now available, it is impossible to review all the proposals which have been made and received serious attention in recent years. Therefore, I will restrict my discussion here to two avenues of inquiry: studies of category processing, which initially arose out of the parallelism hypothesis, and studies of sentence comprehension. In the former case, an explicit effort has been made to account for impairments in the context of specifically proposed normal sentence processing mechanisms, while in the latter case the emphasis has been to account for comprehension impairments in the context of recent theories of grammatical representation. While the work on category processing, which has investigated the so-called open-class/closed-class distinction, might be considered a failure since it has not yielded a viable

hypothesis to account for the comprehension deficit of Agrammatic Broca's aphasics, it is a success story in that it illustrates how there can be a productive interaction between Neurolinguistics and Psycholinguistics. The work on sentence comprehension using the government-binding theory of grammar has not, on the surface, been a success either if success is solely measured on the basis of propounding a truly viable hypothesis. However, I would argue that this work has been highly successful since it represents an ongoing effort to understand the representation of language in the brain in precise representational terms.

## 2.1. The Open-Class/Closed-Class Distinction

That the closed-class vocabulary is somehow compromised is definitional of agrammatism; the question has always been the scope and source/cause of the compromise.

One significant line of research has focused directly on the possible processing distinction between the open- and closed-classes as superordinate syntactic categories. In 1980, Bradley, Garrett, and Zurif argued that in normal language processing two lexica are used, one restricted to closed-class items and the other encompassing all closed- and open-class items. An intuitive argument was made for postulating two lexica: The closed-class, as its name suggests, contains quite a small number of items and, therefore, can be rapidly and exhaustively searched easily; since closed-class items provide potent cues to syntactic structure, it would be an asset to an on-line processor to be able to rapidly and selectively access this part of the vocabulary. Data from normal subjects were presented to show a dissociation of vocabulary types. Based on experimental findings from aphasic subjects, Bradley and her colleagues argued that the closed-class lexical access system is compromised in agrammatism. In a wide variety of studies using both visual and auditory tasks (primarily lexical decision) there was a relatively consistent failure to replicate some or all of the findings of Bradley et al. with neurologically intact subjects and/or with Agrammatic subjects (Gordon and Caramazza, 1982, 1983, 1985; Friederici and Heeschen, 1983; Matthei and Kean, 1989; Segui, Mehler, Frauenfelder, and Morton, 1982). However, there were some partial replications (e.g., Friederici, 1985; Matthei and Kean, 1989; Shapiro and Jensen, 1986). Such work led to the proposal that the compromise of agrammatism in comprehension was not with the ability to access closed-class items, but rather with post-access processes associated with closed-class items. Most recently, this view has evolved into the notion that the underlying cause of agrammatism involves the *use* of closed class items in real time (Friederici, 1988; Garrett, 1992; Zurif, Swinney, Prather, Solomon, and Bushell, 1993; Pulvermüller, 1995; Blackwell and Bates, 1995). What is striking about all of this work is that in no case have syntactic categories been systematically contrasted in an on-line sentence processing study in which both normal and aphasic subjects participated, thus the hypotheses put forward are empirically quite tenuous.

In order to study the processing of syntactic categories, we carried out a study in which we contrasted both specific syntactic categories and the general open-/closed-class distinction. The

task selected was 'identical word monitoring', a task in which a subject hears a target word followed by a sentence in which the target word appears; the subject presses a response key as soon as he recognizes the target word in a sentence. The materials consisted of 'minimal pairs' of sentences such as those in (3), where the word in italics is the target.

3. a. *Some animals EAT ANTS and other kinds of insects*

*Some animals EAT IN their dens instead of in the open*

b. *Modern artists paint ON THIN paper and fabrics*

*Modern artists paint ON THE sides of buildings*

The stimuli were constructed so that each sentence pair consisted of an item where the target was an open-class word and a target where the target was a closed-class word. The open-class target categories used were Noun, Verb, and Adjective, and the closed-class target categories were Preposition, Quantifier, and Determiner. Because many verbs in Dutch do not have overt inflection in sentences, the distinction between verbs with and without overt inflection (V+ and V—, respectively) was also systematically manipulated. Each target category contrast occurred in a sentence pair in word order positions 4, 5, and 6 to control for word position effects. Furthermore, the contexts of the targets was systematically manipulated so that for half the pairs the word preceding the target was an open-class item and for the other half the preceding word was a closed-class item (e.g., EAT vs. ON in (3)). This manipulation was essential since it is well-established that in the identical word monitoring task responses to targets can be influenced by the immediately preceding word. Two such pairs were constructed for each category contrast allowed; an example from the Dutch materials used in this study is provided in (4) and (5).

4. a. *Kinderen kunnen MEER ZIEN door voor in*

Children can more see by in front of

*da groep te gaan staan*

the group standing

b. *Kinderen kunnen MEER DOOR hun vrienden worden beïnvloed*

Children can more by their friends be influenced than you think

*dan je denkt*

5. a. *Leraren kunnen VEEL ZIEN in sommige oudere leerlingen*

Teachers can much see in some older students

b. *Leraren kunnen VEEL DOOR hun leerlingen worden gepest*

Teachers can much by their students be pestered

Two tapes were constructed; on one tape sentences (4a) and (5b) occurred, and on the other



sentences (4b) and (5a) occurred. Subjects were tested on two occasions, hearing one tape in the first test session and the other in the second test session. Thus, all subjects heard all 240 stimulus items as well as 60 filler items, 30 with targets in word order position 3 and 30 in word order position 7 and the targets for each position equally divided between open and closed-class items. The subjects, 36 normals, 8 Broca's aphasics, and 7 Wernicke's aphasics were all native speakers of Dutch.

In order to demonstrate that there is such a thing as an open-class/closed-class distinction which is systematically honored in language processing, it would be necessary to show that *each* closed-class item varied from *each* open-class item as well as showing that the two superordinate classes differed significantly from each other. While the latter finding was obtained for all three subject groups, there was no systematic distinction between the specific categories of the open-class and the specific categories of the closed-class for any subject population (Tables 1, 2, and 3).

	V- (263)	P (299)	Q (318)	V+ (326)	A (336)	N (337)	D (342)
V-	—	ns	ns	***	***	***	***
P		—	ns	ns	ns	***	***
Q			—	ns	ns	ns	***
V+				—	ns	ns	ns
A					—	ns	ns
N						—	ns
D							—

Table 1  
Results of post hoc Newman-Kuels comparison of normal subjects' mean reaction times (in parentheses) to target categories (\*\* =  $p < 0.01$ )

	V- (408)	P (499)	Q (458)	V+ (459)	A (461)	N (444)	D (529)
V-	—	***	***	***	***	***	***
P		—	ns	ns	ns	*	***
Q			—	ns	ns	ns	***
V+				—	ns	ns	***
A					—	*	***
N						—	***
D							—

Table 2  
Results of post-hoc Newman Kuels comparison of Broca's aphasic subjects' mean reaction times (in parentheses) to target categories (\* =  $p < 0.05$ ; \*\*\* =  $p < 0.01$ )

	V- (377)	P (441)	Q (434)	V+ (420)	A (417)	N (411)	D (481)
V-	—	***	***	***	***	***	***
P		—	ns	ns	ns	ns	***
Q			—	ns	ns	ns	***
V+				—	ns	ns	***
A					—	ns	***
N						—	***
D							—

Table 3  
Results of post hoc Newman Kuels comparison of Wernicke's aphasic subjects' mean reaction times (in parentheses) to target categories (\*\* =  $p < 0.01$ )

With respect to specific categories, for all populations verbs without overt inflection showed a significantly different mean response latency from inflected verbs, adjectives, nouns, and determiners, and determiners were significantly different from prepositions. That is, categories which would be expected to differ from each other under any of the versions of the open-class/closed-class processing hypotheses did not, e.g., in no population did prepositions or quantifiers differ from inflected verbs or adjectives. At the same time, categories which would *not* be anticipated to differ from each other did, e.g., in all populations verbs without overt inflection differed from all the other open-class categories, and, also for all populations, determiners differed from at least one of the closed-class categories. These findings support the notion that the so-called open-class/closed-class distinction is an artifact of summing across categories. While the patients had slower reaction times than the normal subjects, globally their performance showed the same pattern as that encountered with normals.

In order to further investigate the data for evidence of the open-class/closed-class distinction, the patients' error data were considered. There was no difference between the two aphasic populations in terms of error rate, and the pattern of errors was the same for both groups, e.g., among the Broca's there were 11 failures to respond to Adjectives, 24 failures to respond to uninflected verbs, and 25 failures to respond to Quantifiers, while the Wernicke's had 15, 23, and 24 failures to respond on these categories, respectively. Both patient groups showed significantly more errors with the closed-class categories than with the open-class categories, but this can be attributed to the comparably high rate of failure to respond to determiners by both groups of aphasics. Thus, when the open-class/closed-class distinction is investigated in detail one finds that not only is there an absence of evidence supporting its role in normal processing but there is also an absence of evidence supporting its role in distinguishing Broca's aphasics from Wernicke's aphasics in sentence comprehension.

In recent work a new approach to the open-class/closed-class distinction can be found in work which distinguishes functional categories from lexical categories and their syntactic projections. Both Hagiwara (1995) and Friedmann and Grodzinsky (1994) have taken this approach. While the cases they discuss are restricted, the general idea bears consideration. Put generally, the idea would be that Agrammatic aphasics have a deficit with respect to functor or specifier categories; in any structure where one of these categories appears, all nodes above it are defective. One consequence of such an approach is that it predicts that there will be impairments in sentence processing for sentences in which anomalous performance is not overtly the result of problems with some specific closed-class item(s). This is a line of conjecture which is potentially promising for the analysis of both normal and impaired sentence processing.

## 2.2. Government-Binding approaches to agrammatism

Since the mid-1980's, a major avenue of research into the study of agrammatism has been syntactic analyses of so-called 'Agrammatic comprehension' carried out within the government-

binding grammatical framework. In this work 'Agrammatic comprehension' refers not just to comprehension problems which are directly attributable to the closed-class, but rather to the comprehension deficits of patients whose speech is Agrammatic and who exhibit the following performance constellation on comprehension tasks.

- (6) Chance Level Performance
  - a. Center-Embedded Object Relatives (Caramazza and Zurif, 1976):  
*The dog that the horse is kicking is brown*
  - b. Reversible Syntactic Passives (Schwartz, Saffran, and Marin, 1980):  
*The boy is chased by the girl*
  - c. Right-Branching Object Relatives (Grodzinsky, 1984):  
*Show me the boy that the girl pushed*
  - d. Object Clefts (Caplan and Futter, 1986):  
*It was the horse that the dog chased*
- (7) Above Chance Performance
  - a. Center-Embedded Subject Relatives (Grodzinsky, 1984):  
*The horse that is kicking the dog is brown*
  - b. Reversible Active Sentences ((Schwartz, Saffran, and Marin, 1980):  
*The boy chased the girl*
  - c. Right-Branching Subject Relatives (Grodzinsky, 1984):  
*Show me the boy that the girl is pushing*
  - d. Subject Clefts (Caplan and Futter, 1986):  
*It was the horse that chased the dog*

A variety of proposals have been put forward to account for this range of data, just a few of which that are closely related will be considered here to illustrate how vibrant this line of research has become.

Grodzinsky's (1986a,b) Trace Deletion Hypothesis (TDH) provided one of the first attempts to account for the pattern of Agrammatic comprehension, (6) and (7), within the framework of Chomsky (1981). His basic observation was that comprehension is seemingly impaired where there is movement from object position but not when there is movement from subject position. In the normal case, where there is movement, a trace of the moved element remains at its original locus, and this trace and the moved element are co-indexed. Theta-roles (e.g., AGENT, THEME) assignment is mediated by a chain between the trace and the moved element. In Agrammatic comprehension, Grodzinsky argued, the trace is deleted or invisible, and it is, therefore, impossible for the moved element to be assigned a theta-role via the chain. Chance performance on sentences such as those in (6) arises because, when an item is not assigned a theta-role, the Default Principle (8), takes over.

## 8) The Default Principle

An NP which is not assigned a thematic role...should be assigned a theta-role according to a *list* which universally associates default values with positions.

[Grodzinsky, 1986a, p. 145]

This principle, which is not developed on the basis of linguistic considerations but rather through experience, will assign an agent role to clause initial nouns in English. Thus, in a sentence such as *The dog that the horse is kicking is brown* both *dog* and *horse* will be assigned AGENT, which is the source of the chance performance on such sentences. As has frequently been observed, a central problem with this proposal is that the Default Principle is ad hoc —not based on any established psychological or psycholinguistic principles of strategies— and consequently difficult to evaluate.

Hickok (1992) observes that there are aspects of Agrammatic comprehension which Grodzinsky's TDH cannot account for: (a) Hickok and his colleagues found that for sentences such as *The tiger that chased the lion is big* comprehension performance of agrammatics was below chance even though there is mediating between the subject and matrix predicate. (b) Caplan and Futter (1986) and Caplan and Hildebrandt (1988) observed chance level performance with two verb subject-relative constructions, e.g., *The horse that chased the cow kicked the pig*. And, (c) Caplan and Hildebrandt (1988) and Grodzinsky and his colleagues (reported in Grodzinsky, 1990) reported chance level performance on simple sentences with pronouns like *The girl pushed her*. To account for these data as well as those in (6) and (7), Hickok proposes the Revised Trace Deletion Hypothesis (RTDH) in which it is also claimed that traces are deleted or inaccessible.

The RTDH is based on the syntactic assumption of the VP-Internal Subject Hypothesis under which subjects are based generated in the Spec of VP, where they receive their theta-role, and then move to Spec of IP to receive Case at S-Structure. Hickok's analysis also, crucially, makes use of the thematic assignment representation of a verb; this representation is of the form «Verb (x (y))», where x denotes the external argument of the verb and y the internal one (Williams, 1981; Grimshaw, 1990), and unspecified arguments are denoted \*. For example, the thematic representation assignment for *The girl chased the boy*, [<sub>IP</sub> The girl [<sub>VP</sub> \* chased the boy] would be *chase* (\* (boy)); *girl*. Hickok proposes that it is just such representations which are available to the general cognitive system. In sentences such as those in (7), where performance is above chance, an internal argument is specified and only one NP is left to be interpreted as the agent. In contrast, for sentences such as those in (6 a, b, and d), there is more than one NP available for interpretation as the unspecified arguments leading to indeterminacy, hence chance performance. Having thus accounted for the basic cases, the RTDH also provides a fairly straightforward analysis for the other cases of chance performance at issue. There are two features of note in the RTDH: First, it provides an analysis of a wider range of data than does the original TDH. Second, it does not require resort to an ad hoc strategy such as the Default

Principle. A serious weakness of the RTDH, as well as the TDH, is that neither can account for cases of performance which is below chance as has been reported by Grodzinsky et al. (1988) with passives of psych verbs, e.g., *The man is adored by the woman*.

The only data considered in both Grodzinsky's original TDH and Hickok's RTDH involve NP movement. If some variant of either general theory were correct, then it would be expected that Agrammatic aphasics would have difficulties in comprehension with sentences which involve verb movement. However, Lonzi and Luzzatti (1993) have suggested that agrammatics are not impaired in processing sentences with verb movement. To address this finding, Grodzinsky (1995) proposes that only traces in theta-positions are deleted (or invisible) in Agrammatic sentence representations. At the same time, he restricts the Default Principle, proposing a variant, the R(eferential) Strategy, which assigns a referential NP a theta-role «by its linear position» just in case it has no theta-role. The R Strategy is claimed to be a non-linguistic strategy which does not apply to non-referential NP's. However, if the R Strategy is a non-linguistic strategy, how can it critically be sensitive to a specific linguistic distinction, that between referential and non-referential elements.

The issue of referentiality has emerged in recent years as a key topic in the analysis of agrammatic comprehension. To take one example, Avrutin and Hickok (1992) engage this topic through consideration of *Which-N* questions, involving subject and object extraction (9), *Who* questions, which involve a bare wh-operator (10).

9. *Which horse chased the giraffe?* (subject extraction)  
*Which horse did the giraffe chase?* (object extraction)
10. *Who chased the giraffe?* (subject extraction)  
*Who did the giraffe chase?* (object extraction)

The account they propose is based on the linguistic distinction between *binding* and *government*. Binding relations are generally unbounded and formed by the movement of a referential element, while government relations are bounded by locality principles and arise from movement of non-referential elements (Rizzi, 1990). Building on this, Cinque (1990) proposes that *which-NP* head binding chains while bare wh-operators head government chains. Avrutin and Hickok (1992) presented actions scenarios to Agrammatic patients and then asked either a *which-NP* or *who* question. Performance on subject extracted NP's for *which questions* was above chance, while performance on object extraction *which questions* was at chance. For both subject and object extraction *who questions*, performance was above chance. To account for these data, they propose that the deficit of agrammatism involves binding chains but not government chains; the asymmetry with *which questions* is explained by the preservation of government chains. [See also, Hickok and Avrutin, 1995.] As Grodzinsky (1995) has observed, this account seems to fail to account for the passive data since passives do not involve binding chains in Cinque's theory. Another problem with this analysis is that it seemingly predicts above

chance performance with object clefts and object relatives, which is contrary to the observations of Agrammatic comprehension.

What is striking about this line of research is its overwhelming success in invigorating research on agrammatism and bringing detailed and current linguistic theory to bear on the analysis of agrammatism. Such research illustrates how far we have come since the work of Caramazza and Zurif in 1976; at that point it was a breakthrough to observe simply that agrammatics had a problem in computing syntactic representations. Because of the detail of the hypotheses being put forward, they are easily falsified, but, more importantly, they suggest new areas of investigation. Beyond that, this research raises significant questions about the mechanisms of normal processing. For example, one of the conjectures of Avrutin and Hickok (1992) is that there are differential processing mechanisms for binding and government chains with binding chains demanding more processing resources because they involve potentially unbounded relations. In this, neurolinguistic research is posing a significant question for the understanding of normal sentence processing.

### 3. *What's Next?*

It is clear that the burst of research activity which was set off following the work of Caramazza and Zurif has been highly productive. Not only do we now know that there is a comprehension deficit associated with agrammatism, but the details of that deficit are only beginning to be understood. It is clear that this approach will continue to be fruitful. However, there are two serious weaknesses with the work that is being done that need to be addressed in the future. First, while there have been great advances in the study of comprehension, there has been relatively little research on production. Agrammatic Broca's aphasics have both production and comprehension deficits and both facets of the disorder demand exploration. The hypothesis of parallelism has been abandoned for no empirical reason, rather it has simply become irrelevant to most investigators. Whether or not there is parallelism —or even partial parallelism— has major implications for our understanding of the structure of normal linguistic capacity. Aphasia research offers a unique window on both representation and computation in production and comprehension which it is a mistake to ignore. Second, despite the wealth of available data and the implications of the analyses of those data for theories of normal processing, there has as yet been relatively little attempt to connect hypotheses related to Agrammatic deficit to explicit theories of computational processes for normal representation. It will only be when approaches to normal processing in adults show the same vigor and attention to linguistic detail as aphasiological research as work such as that described here that neurolinguistic research will make the contribution, which is its potential, to our understanding of the organization of linguistic capacity. Thus, there are important areas which we have yet to provide sufficient attention to.

The advent of imaging technologies and their increasing availability for research will provide us with a new means of assessing the organization of language in the brain. As viable techniques are developed for exploiting imaging technologies to investigate questions of detail and subtlety in syntax, studies with both normal and aphasic subjects will give us a new window on the representation of language in the brain. Where those investigations will lead us is unknown, but it is certain that the excitement of the past two decades will come to pale by comparison.

## References

AVRUTIN, S. AND HICKOK, G. (1992) «Operator/variable Relations, Referentiality, and Agrammatic Comprehension», Ms. MIT.

BLACKWELL A., AND BATES, E. (1995) «Inducing Agrammatic Profiles in Normals: Evidence for Selective Vulnerability of Morphology under Cognitive Resource Limitations», *Journal of Cognitive Neuroscience*, 7: 228-257.

BRADLEY, D., GARRETT, M., AND ZURIF, E. (1980) «Syntactic Deficits in Broca's Aphasia». In D. Caplan (Ed.), *Biological studies of mental processes*. Cambridge, MA: MIT Press.

CAPLAN, D. AND FUTTER, C. (1986) «Assignment of Thematic Roles to Nouns in Sentence Comprehension by an Agrammatic Patient», *Brain and Language*, 27: 117-134.

CAPLAN, D. AND HILDEBRANDT, N. (1988) *Disorders of Syntactic Comprehension*. Cambridge, MA: MIT Press.

CARAMAZZA, A. AND ZURIF, E. (1976) «Dissociation of Algorithmic and Heuristic Processes in Language Comprehension: Evidence from Aphasia», *Brain and Language*, 3: 572-582.

CHOMSKY, N. (1965) *Aspects of the Theory of Syntax*. Cambridge, MA: MIT Press.

CHOMSKY, N. (1981) *Lectures on Government and Binding*. Dordrecht: Foris.

CINQUE, G. (1990) *Types of A' dependencies*. Cambridge, MA: MIT Press.

FRIEDERICI, A. (1985) «Levels of Processing and Vocabulary Type: Evidence from On-line Comprehension in Normals and Agrammatics», *Cognition*, 19: 133-166.

FRIEDERICI, A. (1988) «Agrammatic Comprehension: Picture of a Computational Mismatch», *Aphasiology*, 2: 279-284.



FRIEDERICI, A. AND HEESCHEN, C. (1983) «Lexical Decision of Inflected Open Class Items and Inflected Closed Class Items», *Academy of Aphasia*. Minneapolis, MN.

FRIEDMANN, N. AND GRODZINSKY, Y. (1994) «Verb Inflection in Agrammatism: A Dissociation between Tense and Agreement», *Academy of Aphasia*, Boston, MA.

GARRETT, M. (1992) «Disorders of Lexical Selection», *Cognition*, 42: 143-180.

GESCHWIND, N. (1965) «Disconnection Syndromes in Animals and Man», *Brain* 88: 237-294 and 585-644.

GLEITMAN, H. (1995) *Psychology*. New York: Norton.

GORDON, B. AND CARAMAZZA, A. (1982) «Lexical Decision for Open- and Closed-class Words: Failure to Replicate Differential Frequency Sensitivity», *Brain and Language*, 15: 143-160.

GORDON, B. AND CARAMAZZA, A. (1983) «Closed- and Open-class Lexical Access in Agrammatic and Fluent Aphasics», *Brain and Language*, 19, 335-345.

GORDON, B. AND CARAMAZZA, A. (1985) «Lexical Access and Frequency Sensitivity: Frequency Saturation and Open/closed-class Equivalence», *Brain and Language*, 21, 95-115.

GRIMSHAW, J. (1990) *Argument Structure*. Cambridge, MA: MIT Press

GRODZINSKY, Y. (1984) *Language Deficits and Linguistic Theory*. Unpublished dissertation, Brandeis University.

GRODZINSKY, Y. (1986a) «Language Deficits and the Theory of Syntax», *Brain and Language*, 27: 135-159.

GRODZINSKY, Y. (1986b) «Neurological Constraints on Linguistic Theories». In N. Fukui, T.R. Rapaport, and E. Sagey (eds.), *MIT Working Papers in Linguistics*, 8: 173-190.

GRODZINSKY, Y. (1995) «A Restrictive Theory of Agrammatic Comprehension», *Brain and Language*, 50: 27-51.

GRODZINSKY, Y., FINKELSTEIN D., NICOL, J., AND ZURIF, E.B.(1988) «Agrammatic Comprehension and the Thematic Structure of Verbs», *Academy of Aphasia*, Montreal.

GRODZINSKY, Y. AND FINKEL, L. (1996) «Severe Grammaticality Judgment Deficits in Agrammatism and Wernicke's Aphasia», *Academy of Aphasia*, London.

HAGIWARA, H. (1995) «The Breakdown of Functional Categories and the Economy of Derivation», *Brain and Language*, 50: 92-116.

HEILMAN, K.M., AND SCHOLLES, R.J. (1976) «The Nature of Comprehension Errors in Broca's, Conduction and Wernicke's Aphasics», *Cortex*, 12: 258-265.

HICKOK, G. (1992) «Agrammatic Comprehension and the Trace-deletion Hypothesis», MIT Department of Brain and Cognitive Sciences Occasional Papers, 45. #

HICKOK, G. AND AVRUTEN, S. (1995) «Representation, Referentiality, and Processing in Agrammatic Comprehension: Two Case Studies», *Brain and Language*, 50: 10-26.

KEAN, M-L (1977) «The Linguistic Interpretation of Aphasic Syndromes: Agrammatism in Broca's Aphasia», *Cognition*, 5: 9-46.

KEGL, J. (1995) «Levels of Representation and Units of Access Relevant to Agrammatism», *Brain and Language*, 50: 151-200.

KOLK, H.H.J., VAN GRUNSVEN, M.J.F., AND KEYSER, A. (1982) «On Parallelism in Agrammatism: A Case Study» #

LENNEBERG, E. (1967) *Biological foundations of language*. New York: Wiley.

LESSER, R. (1974) «Verbal Comprehension in Aphasia: An English Version of Three Italian Tests», *Cortex*, 10: 247-263.

LINEBARGER, M., SCHWARTZ, M.F., AND SAFFRAN, E. (1983) «Sensitivity to Grammatical Structure in So-called Agrammatic Aphasics», *Cognition*, 13: 361-392.

LONZI, L. AND LUZZATTI, C. (1993) «Relevance of Adverb Distribution for the Analysis of Sentence Representation in Agrammatic Patients», *Brain and Language*, 45: 306-317.

MATTHEI, E. AND KEAN, M-L (1989) «Post-access Processes in the Open vs. Closed Class Distinction», *Brain and Language*, 36: 163-180.

MICELI, G., MAZZUCHINI, A., MENN, L., AND GOODGLASS, H. (1983) «Contrasting Cases of Italian Agrammatic Aphasia without Comprehension Disorder», *Brain and Language*, 19: 65-97.

- PARISI, D., AND PIZZAMIGLIO, L. (1970) «Syntactic Comprehension in Aphasia», *Cortex*, 6: 204-215.
- PULVERMÜLLER, F. (1995) «Agrammatism: Behavioral Description and Neurological Explanation», *Journal of Cognitive Neuroscience*, 7: 271-281.
- RIZZI, L. (1990) *Relativized minimality*. Cambridge, MA: MIT Press.
- SCHWARTZ, M., SAFFRAN, E., AND MARIN, O. (1980) «The Word Order Problem in Agrammatism: I. Comprehension», *Brain and Language*, 10: 249-262.
- SEGUI, J., MEHLER, J., FRAUENFELDER, U., AND MORTON, J. (1982) «The Word Frequency Effect in Lexical Access», *Neuropsychologia*, 20, 615-627.
- SHANKWEILER, D., CRAIN, S., GORRELL, P., AND TULLER, B. (1989) «Reception of Language in Broca's Aphasia», *Language and Cognitive Processes*, 4: 1-33.
- SHAPIRO, L. AND JENSEN, L. (1986) «Processing Open and Closed Class-headed Words: Left Hemisphere Support for Separate Vocabularies», *Brain and Language*, 28, 303-317.
- WERNICKE, C. (1874) *Der aphasische Symptomcomplex: Eine psychologische Studie auf anatomische Basis*. Breslau: Cohen & Weigert.
- WILLIAMS, E.S. (1981) «Argument Structure and Morphology», *The Linguistic Review*, 1: 81-114.
- WULFECK, B., BATES, E., AND CAPASSO, R. (1991) «A Cross-linguistic Study of Grammaticality Judgments in Broca's Aphasia», *Brain and Language*, 41, 311-336.
- ZURIF, E.B., AND CARAMAZZA, A. (1976) Psycholinguistic Structures in Aphasia: Studies in Syntax and Semantics«. In H. Whitaker and H. Whitaker (eds.), *Studies in Neurolinguistics, Vol. 1*. New York: Academic Press.
- ZURIF, E.B., SWINNEY, D., PRATHER, P. SOLOMON, J., AND BUSHELL, C. (1993) »An On-line Analysis of Syntactic Processing in Broca's and Wernicke's Aphasia«. *Brain and Language*, 45: 448-465.